Review Draft EPA Report "Investigation of Ground Water Contamination near Pavillion, WY" – December 2011 EPA-ORD NRMRL Laboratory Ada, OK DiGiulio et.al.

General Comments:

This phased investigation of ground water contamination of both shallow (<200mbgs) and deep (>230mbgs) wells is comprehensive and clearly shows two major conclusions. The first is that pits for the storage/disposal of drilling wastes and produced waters have contaminated shallow (<30m) domestic and stock wells with monoaromatic hydrocarbons, gasoline range organics (GRO) and diesel range organics (DRO). Once the extent of the shallow contamination and hydraulic gradients are better understood, there exists methods to remediate the contamination.

The second major conclusion regarding elevated: CH_4, Cl^-, K^+, pH and a variety of organic compounds associated with fracturing fluids in the deep wells is supported by a line-of-reasoning approach. Not only was the CH_4 found decidedly of similar isotopic composition indicating thermogenic origin, but the sporadic cement bonding of production well casings over intervals where fracking was practiced clearly provided direct conduits for the transport of methane vertically. The inorganic and organic geochemistry of ground water near some of the poorly cemented production wells can only be explained by the invasion of strong base (KOH) and other fracking fluid constituents (i.e. potassium metaborate, t-butyl alcohol, t-butyl hydroperoxide, and breakdown products) which are unlikely to have come from other sources. The high pH, K^+, and Cl^- alone make the remediation of contaminated water very difficult.

Specific Comments

1. pages 1-4; The discussion of the geologic framework in the Pavilion Area is quite thorough, particularly with respect to complex stratography of the Wind River and Fort Union formations and the similar isotopic signatures of methane, ethane, and propane in these formations.
2. pages 5-16; 2.0 Methods Section: The discussion of :deep well installation, analyses of mud-rotary drilling additives, well construction, and ground water sampling of deep wells in Phases III and IV is comprehensive based on state of the art methods. For example state of the art low-flow purging and sampling (Puls and Barcelona, 1996) techniques were employed in so far as possible given drawdown of water in the wells, gas invasion, and off-gassing (note Figure 9).
3. p15 line 7; ...data collected during Phase I, which is still in progress.
4. p15; Gas Sampling from...Deep Monitoring Wells. The methodology used to conduct the gas sampling is state of the art.
5. p17-22; 30 Results and Discussion. The presentation of results and their accompanying discussion is clear and makes good use of geochemical modeling to identify water types as well as examine gypsum and calcite saturation indices. The differences in inorganic geochemistry between shallow and deep wells are striking with deep concentrations greater than shallow by: Cl- (8x), K+ (8-10.5x), pH (1.2-2x on log10 scale; 10-100x on linear scale). The latter increase is indicative of the addition of strong base (i.e. KOH), most likely from the invasion of fracking

fluids or related treatments. This is clearly shown in the results of reaction path modeling simulating the addition of KOH to the nature ground water.

6. p23-27; Organic Geochemistry: This presentation and discussion of results clearly shows that not only do K^+, Cl^-, CH_4 and pH suggest a deep source of contamination (>299mbgs), but there are very high levels of a range of signature organic compounds which are most unlikely to arise from any other source than hydrofracking. Figure 17 and Table 4 are particularly illustrative of this condition.
7. p27-32; Natural Gas Migration. This section clearly shows the temporal trend in CH_4 appearance at depths less than 300m prior to the blowout of a domestic well at ~159mbgs in 2005. Here the argument would be made stronger by tracking the temporal trends in hydrofracking and production well operation in the last twenty years. Enabled by the poor cementation of production wells this should be no surprise. The discussion (see Fig. 19 & 20) leaves little doubt that the gas production wells provided conduits for natural gas migration into shallow formations.
8. pages 33-39; Conclusions. The concluding section is a concise, comprehensive summary of the major findings of the work.
9. pages B7-B13; Parameter Blanks. Inspection of the data for blanks showed that very few blanks suggested problems with sample handling as the <5% of the data that showed "detects" below the Detection Limit may simply reflect field conditions.
10. pB15; Duplicate Determinations Table B14. Inspections of these data showed acceptable RPD (Relative Percent Difference) except for phenol which is a difficult analyte under the best conditions.

Summary Comments

I think that this was a well conducted hydrogeochemical study of a complex subsurface environment that has been made considerably more complex by virtue of poorly cemented gas production and fracking wells. Considerably more work needs to be done to develop a better understandin g of the extent of contamination, particularly with respect to the waste pits. More work on the deeper contamination must be done very carefully so as not to imperil the investigators or further spread the contamination.